California Market Structure

- California energy "market" is complex
  - A progression of forward and spot markets
    - Day-ahead (consisting of 24 separate hours)
    - Hour-ahead
    - Real-time
  - Separate markets for different commodities
    - Multiple forward energy markets (PX and SCs)
    - Forward transmission market (ISO)
      - Inter-zonal
      - Intra-zonal
    - Multiple ancillary services markets (ISO or self-provision)
    - Single real-time imbalance energy market (ISO).
- The separate markets interact in complex ways

Winning in California Markets

- What strategies will help you prosper in the California market structure?
- Often heard "folk" wisdom:
  - "Bid your true costs and you will maximize your profits."
  - How did this folk wisdom arise?
  - Is it true?

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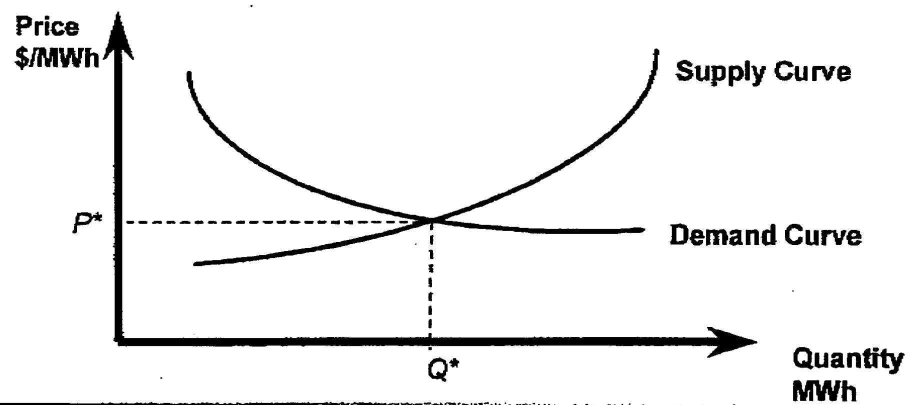
Underlying Economic Theory

- Each individual market is based on a simple supply/demand economic model
  - Operate at intersection of supply and demand curves
    - Socially optimal production and use
    - Market clearing price



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Auction Theory

- Socially optimal production and efficient prices result if producers & consumers bid true supply and demand curves
  - How do you get parties to bid their true costs?
- Auction theory
  - Parties bid true supply and demand curves when
    - Each party is small compared to the market
    - Market is run once (or infrequently)

Reality vs. Economic Theory

- Supply and demand curves are not smooth functions
  - Start-up costs
  - Uncertainty
- Published protocols governing California markets from deviate from theory and physical reality
  - Gaps within a single market
    - Some markets will not “clear” and may be unstable
    - Constraints that couple the schedule in one hour to the schedule in the next hour are ignored
  - Gaps between markets
- Strategies can affect prices

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Reality vs. Auction Theory

- Simple auction model ignores important features
  - Locational market power due to transmission
    - Inter-zonal
    - Intra-zonal
  - Frequently repeated markets
  - Interacting markets
    - Energy
    - Reserves
  - Cooperative behavior among participants
- Parties can bid strategically to take advantage of deviations from theory

Business Rules

- Published business rules and processes need more work
  - Setting ancillary service requirements
  - Interaction with WSCC
  - Communicating real-time instructions to resources
  - Deciding whether a service has been delivered
    - Affects compliance and payments
  - Penalties for non-performance

Strategic Decisions in California

- Decide which forward energy market to use
  - PX or another Scheduling Coordinator
- Decide how to use resources
  - Bid capacity in one market and withhold in others
    - Energy market vs. reserves markets
    - Hour-ahead vs. day-ahead vs. real-time
- Tactical decisions
  - Adjust bid prices
  - Treat physical constraints skipped in protocols when bidding or ignore and lean on ISO

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Steps in Developing Strategies

- Expert analysis
  - Review of business protocols
  - Review of competitor characteristics
  - Identify potential strategies based on experience
- Analytical tools
  - Test possible strategies against computer
  - Test possible strategies against user specified counter strategies
- War gaming
  - Red team, blue team competition
  - Analytical tools provide playing field

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Analysis of Protocols

- Gaps in the protocols provide
  - Opportunities for increased profits
  - Chance for other players to damage your position
- Analyze protocols
  - Find leverage points you can use
  - Find ways to protect against actions of others
  - Develop potential "raw" strategies
    - Prioritize for detailed investigation

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Development of Practical Strategies

- Analysis provides the foundation
  - Analysis of protocols
  - Analysis of competitors
  - Gives start for the development of usable strategies
- Development of practical strategies requires detailed simulation of market operations
  - Impact of your actions
  - Impact of competitors' actions

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Analytical Business Model

- Detailed computational business model of the California markets is required
  - Model protocols and market operation in detail
    - Strike a balance among
      - modeling detail
      - computational resources needed
      - available market information
  - Game theoretic model with multiple participants
- Must accept a wide range of possible strategies and evaluate the outcomes

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Developing Strategies

- Develop strategies that allow you to operate within the protocols and increase your profits
- Workable strategies
  - Do not require unrealizable precision in forecasts
  - Position you to take advantage of opportunities to increase profits when they arise
  - Limit losses if conditions differ from expected
- Examine the range of strategies that others may use to increase their profits
  - Develop counter strategies that limit their detrimental impact on you

Changing Protocols

- ISO/PX will recognize holes as they operate
  - Revise protocols and systems to close the gaps
  - Time lag between recognizing and closing gaps
    - Window of opportunity
  - Closing one gap may open others
- Market rules will be fluid for a while
  - ISO/PX will be pressured to provide new services and capabilities
    - Long-term tradable transmission rights

Ongoing Process

- Strategy development is not static
  - Protocols evolve
  - Competitors learn new strategies
- Strategy development is an ongoing effort
  - Monitor operation of market
  - Monitor actions of competitors
  - Revise strategies to keep pace

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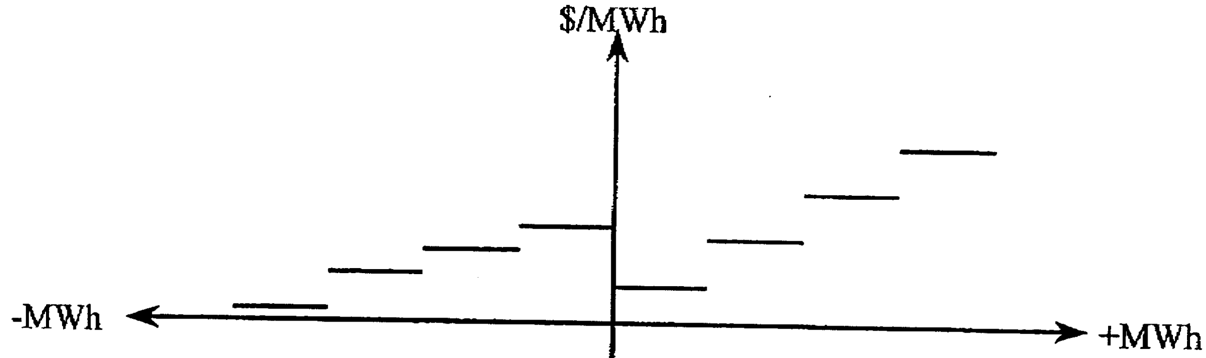
Example of a Protocol Gap

- Perot Systems discovered a "hole" in the ISO's protocols for buying, selling, and pricing imbalance energy
  - Allowed strategies that would destabilize the market
- Points we will cover in this example
  - The way the market would have operated
  - A simple example of a strategy to increase profits
  - The effects on participants, the PX, and the ISO
  - Ways to correct the problem

Merit Order Stack



- Decremental Supplemental Energy Bids

If ISO must reduce energy output

- Incremental Supplemental Energy Bids and Energy from Reserves

If ISO must increase energy output

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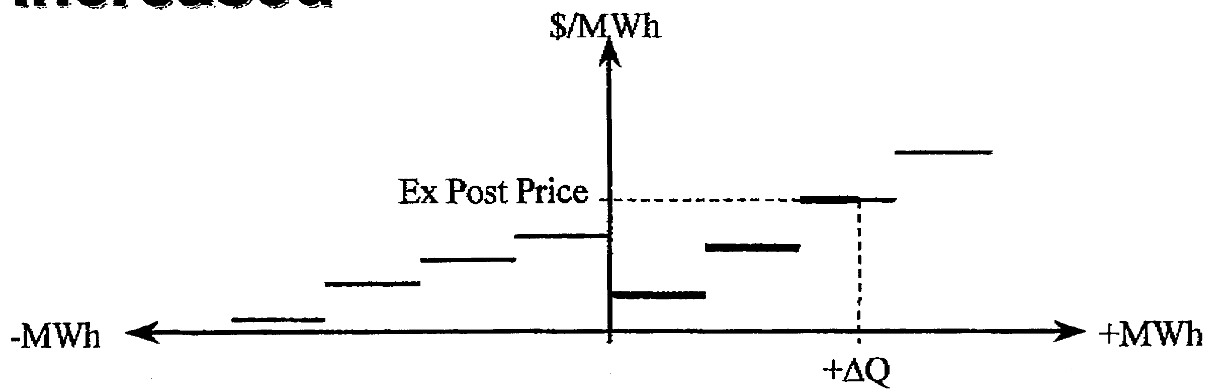
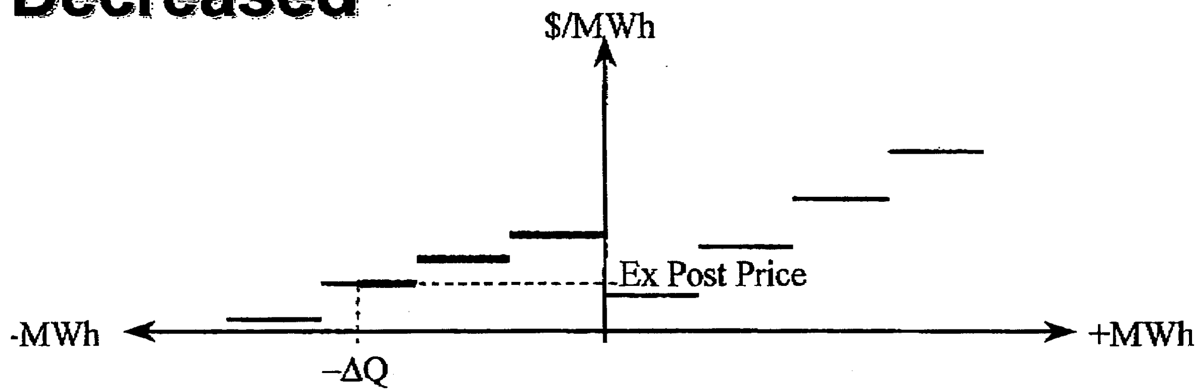
Ex Post Price when Output is Increased



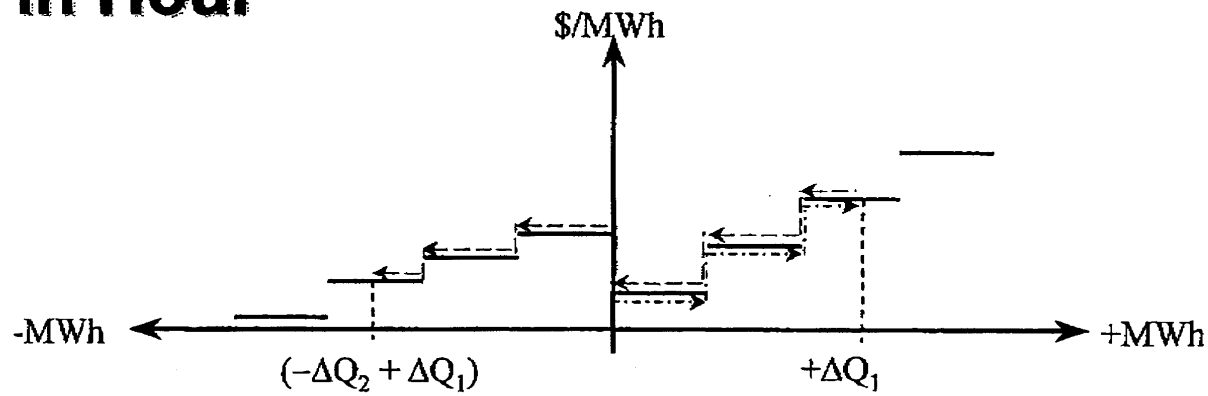
- If additional energy (ΔQ MWh) were needed
  – ISO would dispatch the incremental bids and reserves with available energy in order of increasing bid price
  – Ex post price would be the price of the most expensive resource dispatched

Ex Post Price when Output is Decreased



- If reduction of energy (–ΔQ MWh) were needed
  - ISO would dispatch the decremental energy bids with available reduction in order of decreasing bid price
  - Ex post price would be the price of the least expensive resource dispatched downward

Output Increases then Decreases in Hour



- Increased output of $+\Delta Q_1$ followed by decrease of $-\Delta Q_2$ within the hour, with $\Delta Q_1 < \Delta Q_2$

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Controlling the Real-Time Market

- The structure of the real-time imbalance energy market would have permitted strategies by which a participant could have:
  - controlled the ex post price
  - dumped power on the real time market at a very high ex post price
  - caused wild swings in the ex post price

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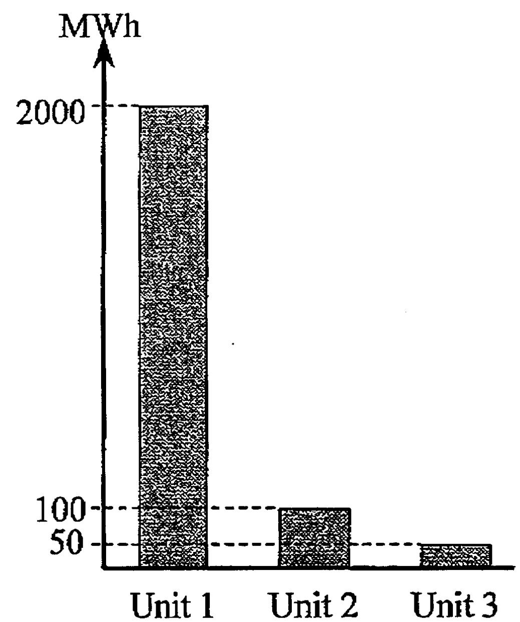
Simplified Example

- Participant P1 has three generation units:
  - Unit 1 with operating limits of [100 MW, 2000 MW]
  - Unit 2 with operating limits of [100 MW, 2000 MW]
  - Unit 3 with operating limits of [50 MW, 100 MW]
- P1 bids to sell 2150 MWh in the forward market (for 1 hour)
  - P1 intentionally forgoes the chance to sell an additional 1950 MWh in the forward market
  - P1 will use this capacity to control the ex post price and sell high-priced imbalance energy

Schedule and Supplemental Bids

Schedules from Forward Market



- Supplemental Energy Bids:
  - Unit 1: Decremental only
    $10,000/MWh for $100 \leq x \leq 2000$
  - Unit 2: No Bid
  - Unit 3: Incremental Micro Bids
    $ 0/MWh for $50 \leq x \leq 55$
    $10/MWh for $55 \leq x \leq 60$
    •
    •
    •
- Suppose that Unit 1 submits highest priced decremental bid to ISO

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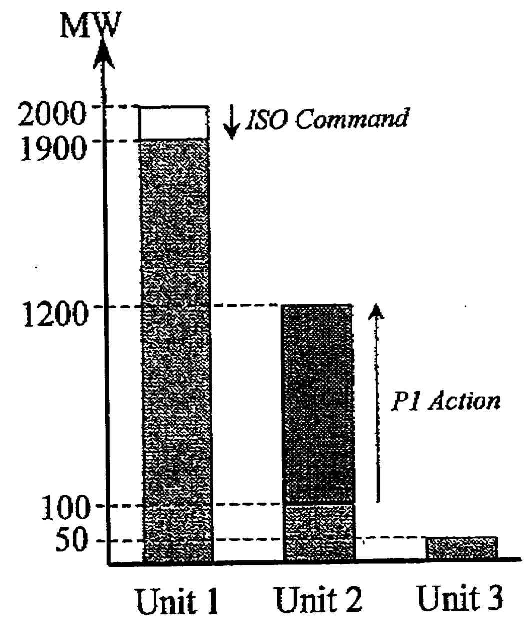
Case 1: ISO Needs Additional Energy



- Suppose ISO needs 1,000 MW more
- ISO will use incremental bids (including Unit 3 which gives P1 information)
- P1 starts to increment Unit 2 on its own
- ISO first backs down previously incremented units
- Unit 2 reaches a point at which ISO will have decremented all previously incremented units and starts reducing the highest priced decremental bid (Unit 1)
- P1 sells 1,000 MWh in imbalance energy market
- Ex post price set by last unit decremented ($10,000/MWh)
- P1 is paid $10,000,000

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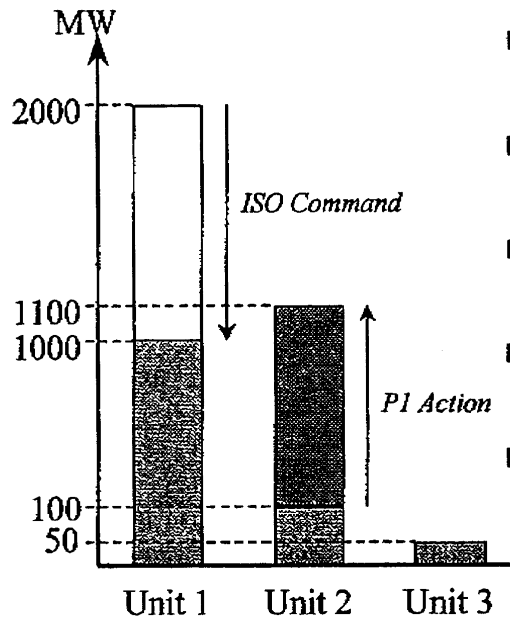
Case 2: ISO Must Reduce Output



- Suppose ISO must reduce by 1,000 MW
- ISO will use decremental bids and back Unit 1 down by 1000 MW
- P1 would have to pay the ISO $10,000,000 to replace Unit 1's output
- P1 eliminates this risk by simultaneously increasing Unit 2 by 1000 MW
- P1's total real-time output is at scheduled value, so P1's net payment to ISO is $0
- ISO has problems:
  - Imbalance persists
  - ISO leans more on regulation
  - Regulation capacity requirements increase so ISO must buy more
  - Ancillary service costs increase

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Effects on Other Participants

- Suppose that a participant usually experiences appreciable error in forecasting its real-time load
  - It would buy and sell energy on the imbalance energy market due to forecasting errors
  - It could experience extreme peaks in its payments for imbalance energy if ex-post price can rise very high
  - It could insure against these peaks:
    - Always schedule more energy in the forward market than it expects that it will need in real-time
      - Usually sells energy on imbalance energy market (or at least reduce the size of its purchases)
      - Additional costs if forward price > ex post price, but reduces its payment peaks for imbalance energy

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Effects on PX

- PX participants would be exposed to swings in ex post price
  - PX participants could insure themselves against effects
  - Grouping participants reduces the amount of extra energy that must be scheduled and the expected cost
  - PX cannot take such a position to insure a group
- Power Marketer (PM) can take a position in a forward market to insure its participants
  - PM takes a position in forward market to sell insurance that PX cannot sell
  - PM attracts participants from the PX

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Effects on ISO

- Parties could have tried to dump considerable energy on the ISO's imbalance energy market
  - ISO would have needed to decrement energy production more than anticipated
  - Decremental supplemental energy bids are voluntary
    - No concept of the ISO buying "negative reserves" to ensure that it will have enough units that it can decrement
    - ISO may have to lean more on regulation
    - ISO may have to administratively reduce some generation
      - Real-time imbalance energy market may "fail" to set an ex post price based on decremental energy bids

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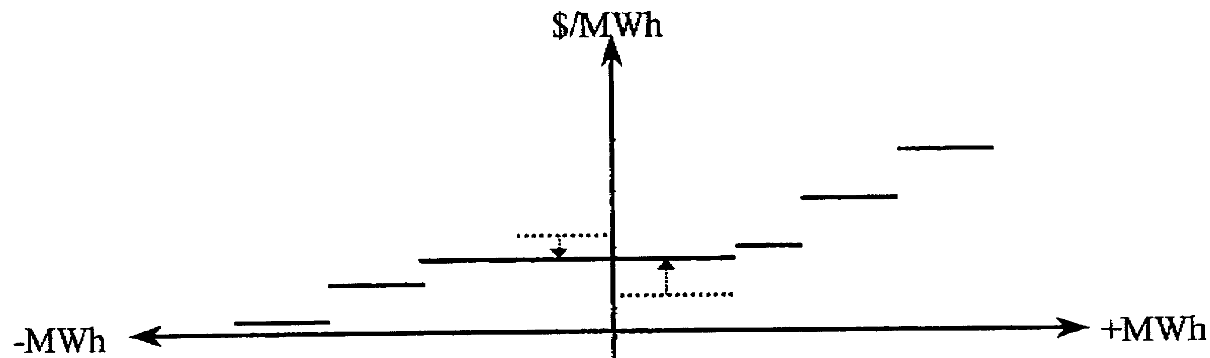
ISO's Correction

- The ISO has revised the protocols to make a market that appears to clear:
  - Calculate the market clearing price (MCP) that would result if the ISO were to clear the real-time energy market
  - For incremental supplies with price less than MCP, raise the price of the supply to the MCP
  - For decremental bids with price more than MCP, lower the price to the MCP
- Effect on strategies unclear
  - Not aware of any strategic studies

"Re-Priced" Merit Order Stack



- Decremental Supplemental Energy Bids
- Incremental Supplemental Energy Bids and Energy from Reserves

If ISO must reduce energy output

If ISO must increase energy output

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Another Protocol Gap

- Perot Systems discovered a "hole" in the PX's protocols for setting zonal energy prices when there is congestion.
  - Adverse interaction with a hole in the ISO's protocols for setting congestion usage charges.
- A small participant could control prices in CA and destabilize the PX market.

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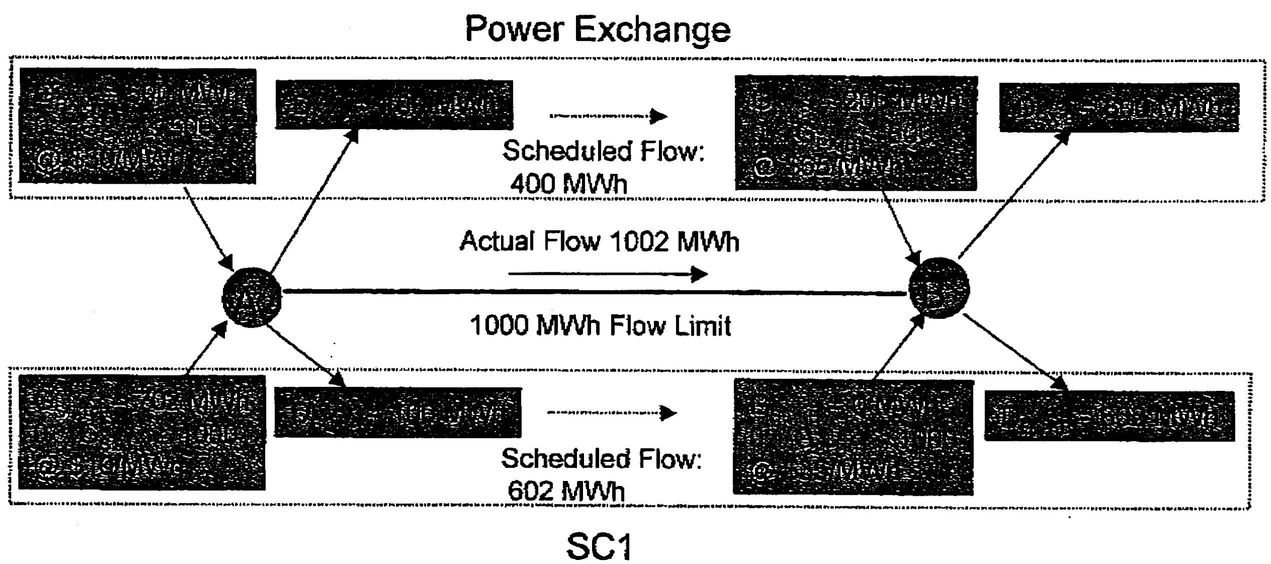
Schedules and Adjustment Bids

- Each SC develops a preferred schedule for its forward market.
  - SC's generation equals its demand in each hour.
- ISO combines SCs' schedules and checks for transmission congestion.
  - SCs provide adjustment bids that are used to eliminate congestion. The bids give:
    - Cost of increasing output from a resource.
    - Savings due to reducing output of a resource.

Example with Congestion

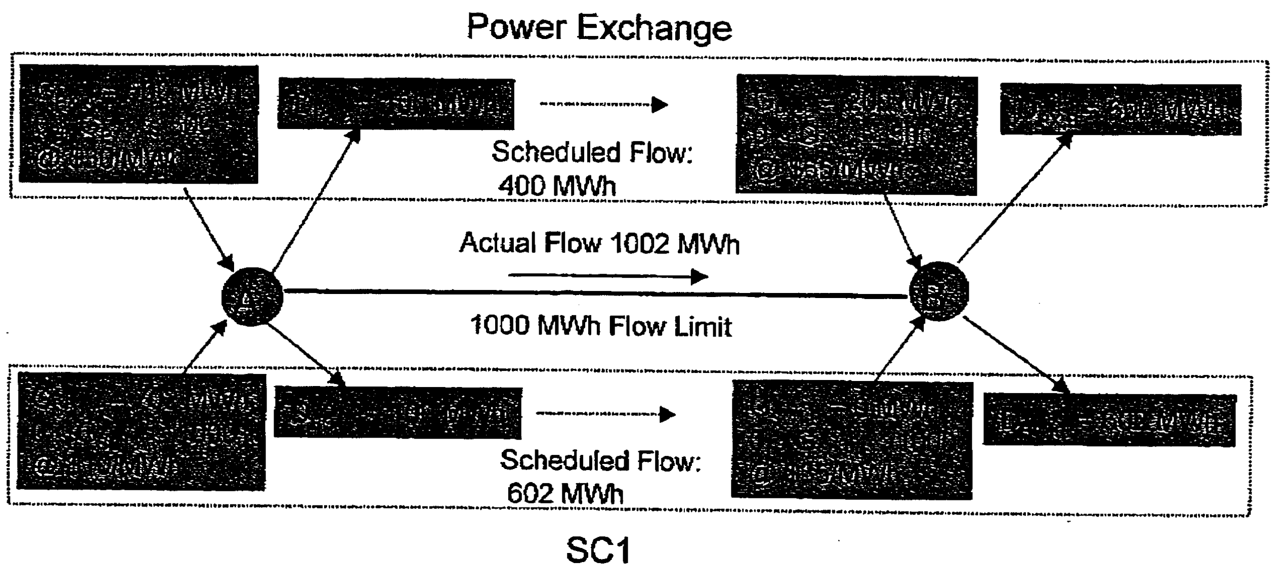


Transmission limit is violated, so ISO must reschedule to eliminate congestion.
How should the ISO reschedule the resources?

Market Separation

- The ISO runs a transmission market.
  - ISO adjusts SCs' schedules to maximize value of transmission usage and eliminate congestion.
  - ISO does not become involved in forward energy markets by arranging trades.
    - ISO keeps each SC's generation in balance with its demands (market separation constraint).
- The SCs' adjustment bids are interpreted as implicit bids to use transmission capacity.

Example with Congestion



PX values transmission capacity at \$65/MW – \$30/MW = \$35/MW
SC1 values transmission capacity at \$35/MW – \$10/MW = \$25/MW
ISO allocates transmission to most valuable use (PX).

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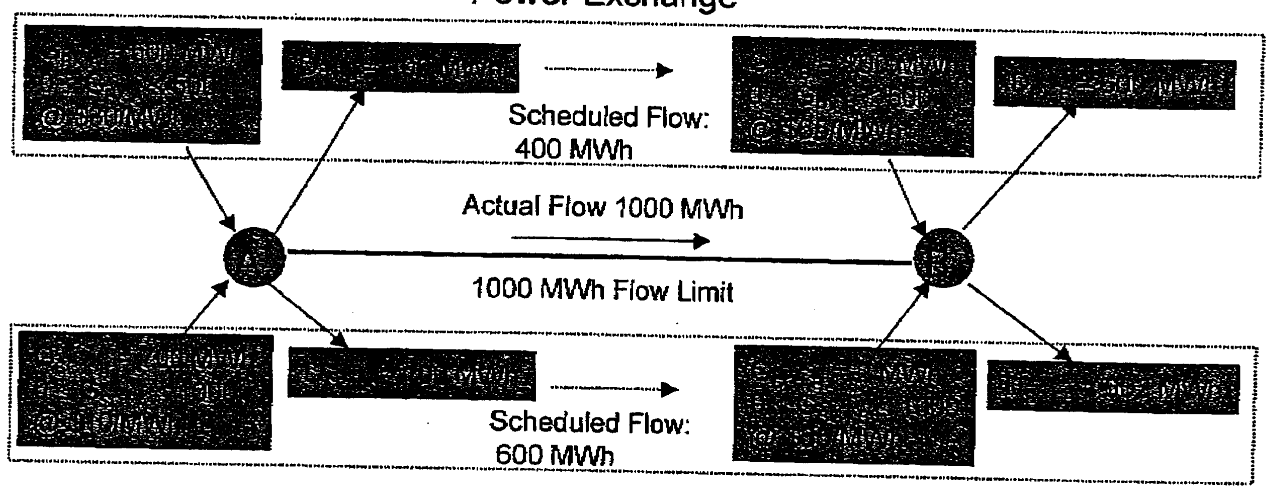
Reschedule to Relieve Congestion

Power Exchange



SC1

ISO shifts 2 MWh of SC1's generation from $G_{SC1,A}$ to $G_{SC1,B}$.
ISO does not arrange trades to lower cost.
Arranging such trades is left to the SCs who run the energy forward markets.

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Congestion Usage Charges and Zonal Marginal Costs

- Usage charge for sending energy from one zone to another is difference between zonal marginal costs.
- Zonal marginal costs depend upon SC:
  - The SCs' forward energy markets are separate.
- Differences do <u>**not**</u> depend upon the SC.
  - Cost of moving a MWh of energy from one zone to another is independent of SC.
- In the example, usage charge is $25/MWh.

PX Zonal Energy Prices

- PX sets zonal energy prices so that:
  - Zonal energy price in each zone ≥ most expensive energy in each zone
  - Differences between zonal energy prices equals ISO's usage charge between the zones
  - Zonal energy prices as low as possible subject to above.
- Zonal energy prices in example:
  - Zone A: $MC_{PX,A}$ = $40/MWh
  - Zone B: $MC_{PX,B}$ = $65/MWh.

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Check of Marginal Costs for PX

- To calculate $MC_{PX,A}$ increment $D_{PX,A}$ by 1 MWh:
  - PX increases $G_{PX,B}$ 1 MWh @ $65/MWh and sends to A.
  - Flow from B to A provides 1 MW of capacity from A to B.
    - SC1 increases $G_{SC1,A}$ 1 MWh @ $10/MWh.
    - SC1 decreases $G_{SC1,B}$ 1 MWh @ $35/MWh.
  - $MC_{PX,A}$ is $65/MWh + $10/MWh – $35/MWh = $40/MWh.
- To calculate $MC_{PX,B}$ increment $D_{PX,B}$ by 1 MWh:
  - PX increases $G_{PX,B}$ 1 MWh @ $65/MWh.
  - $MC_{PX,B}$ is $65/MWh.
- PX's cost of sending energy from A to B is
  $MC_{PX,B} - MC_{PX,A}$ = $25/MWh.

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Hole in PX Protocol

- The PX Protocols required non-negative zonal energy prices.
- If insufficient adjustment bids to alleviate congestion on a path, ISO would:
  - Allocate transmission capacity to SCs pro rata.
  - Set a fixed default usage charge on the path.
    - ISO was planning to use $250/MWh as the default.
- ISO and PX protocols could interact to destabilize the market.

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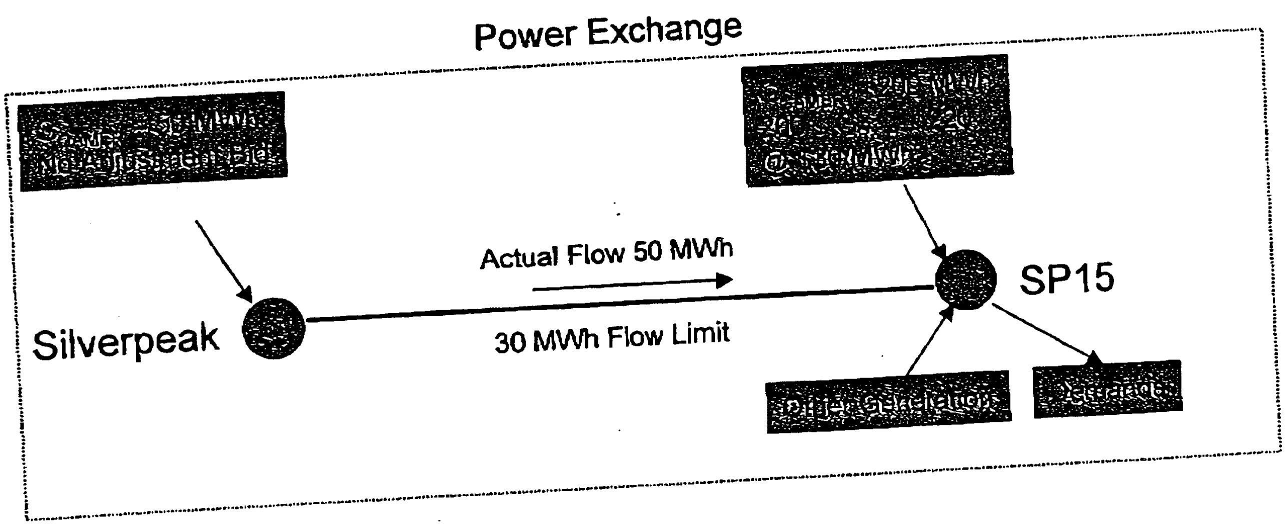
Game ...

- A relatively small PX participant could purposely congest a small interzonal path.
  - Consider Silverpeak intertie (30 MW capacity).
  - Gamer could bid 250 MWh in PX auction at $0/MWh
    - Assume that he wins and PX UMCP = $25/MWh.
  - Gamer would schedule 50 MWh at Silverpeak intertie and 200 MWh in California (SP15).
    - Silverpeak is congested as a result.
  - Gamer would not give a decremental adjustment bid on the 50 MWh he schedule at Silverpeak.
    - ISO will use pro rata allocation and set default usage charge on Silverpeak intertie= $250/MWh.

... Game ...



- ISO shifts 20 MWh of Gamer's generation from Silverpeak.
- ISO sets default usage charge = $250/MWh on path since it ran out of adjustment bids to reduce generation at Silverpeak.
- Assume that ISO uses Gamer's adjustment bid in SP15 to replace the 20 MWh to keep the PX in balance.

... Game

- PX requirements on zonal prices:
  - $ZMCP_{SILVERPEAK,PX} \geq \$0/MWh$.
  - $ZMCP_{SP15,PX} \geq$ Most expensive energy purchased in zone (assume that this is $30/MWh).
  - Difference in PX zonal prices equals ISO usage charge.
    - $ZMCP_{SP15,PX} - ZMCP_{SILVERPEAK,PX} = \$250/MWh$.
- Result
  - $ZMCP_{SILVERPEAK,PX} = \$0/MWh$
  - $ZMCP_{SP15,PX} = \$250/MWh!$
- Gamer was able to increase the price it receives for the 200 MWh it scheduled in SP15 by $220/MWh.

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Corrections

- PX removed requirement for non-negative prices
  - If a participant does not give a decremental adjustment bid, he is saying that he will sell the energy at any price.
  - This price can be negative -- i.e., he will pay the PX to take the energy.
- When the ISO runs out of adjustment bids, the ISO sets the default usage charges based on the adjustment bids that it had received and used.